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United States Outer Continental Shelf Basins: Maps & Descriptions

U.S. Department of the Interior
MMS Minerals Management Service
Offshore Resource Evaluation Division

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Editor

U.S. Department of the Interior
Minerals Management Service
Offshore Resource Evaluation Division

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Conversion Tables

Note: Most of the numbers cited in the text are offered as approximations. The metric equivalents supplied with these numbers are just that, metric equivalents of approximations, and any numerical precision should not be implied.

Meter = Feet/3.281

Kilometer = Mile/0.6214

Introduction

This report is an attempt to identify the location of potential hydrocarbon bearing basins in U.S. Outer Continental Shelf planning areas. The maps and geologic discussions result from an Agency wide effort by geologists and geophysicists.

A basin is a segment of the earth's crust which has been downwarped resulting in an accumulation of sediments which become thicker toward the center of the depression. The choice of connecting points for the periphery of the basin can be based on a wide variety of criteria depending upon the objective of the display. In many cases basins are not defined by the maximum extent of sediment accumulation (i.e., the pinchout point) but by more arbitrary criteria such as points of notable sedimentary thinning.

In this report an attempt has been made to link geologic and geometric concepts of sedimentary basins with an assessment of hydrocarbon potential. These concepts are not mutually inclusive. Although discrete, major sedimentary basins in each Federal lease sale planning area have been depicted on these maps, interbasin or adjacent areas may also have petroleum potential. The basin outlines drawn are intended to circumscribe sedimentary sections believed to hold at least a marginal probability for hydrocarbon generation, expulsion and/or accumulation. Basins outside of the Gulf of Mexico are defined, for the most part, by the one kilometer sediment thickness line and in the Atlantic, also by the Mesozoic shelf-slope break. Arches and platforms separate depocenters and even basins where the criteria above cannot be applied. The onshore extension of the Gulf of Mexico Basin is restricted, by definition, to the limit of the Lower Cretaceous shelf edge. In some of the basins, various depocenters have been identified. These depocenters are sites of maximum deposition within the basin as defined by regional mapping or in the literature. Some have been identified in the literature by specific names, i.e., the Houston Embayment, Carolina Trough, Hanna Trough. In offshore Alaska, where many frontier areas still remain, all depocenters, named and unnamed, are defined by the 3-kilometer sediment thickness line.

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North Atlantic

Regional Geology

The Georges Bank Basin is the major geologic feature of the North Atlantic Planning Area. The basin is an elongated east-west trending depression approximately 350 miles (560 km.) long and 120 miles (190 km.) wide. Sediment thicknesses exceed 30,000 feet (9,100 m.) in several subbasins.

The subsurface of the Georges Bank area consists of pre-rift continental sediments capped by as much as 25,000 feet (7,600 m.) of marine and terrigenous deposits. The lithology appears to be controlled mainly by paleobathymetry and distance from the paleoshoreline. The pre-rift sediments are remnants of Triassic clastics, volcaniclastics, and fluvio-lacustrine deposits that were preserved above grabens which had formed in crystalline and meta-sedimentary basement as a consequence of the rifting process. Younger Triassic coastal sediments unconformably overlie Triassic graben fill.

The rifting process continued in distinct episodes from Late Triassic to Middle Jurassic time. Intrusion of marine waters after the initial rift resulted in the deposition of Late Triassic shallow marine sediments including limestone, dolomite, and evaporites (mostly salt). This section is enriched in clastics and coal in a shoreward direction. Large thicknesses of evaporites deposited in an arid, shoreline environment and deformed by subsequent sediment loading produced diapirs in the northeastern part of the planning area. A widespread erosional unconformity caps the Triassic coastal sequences.

Renewed subsidence, probably associated with an early Jurassic rifting episode, resulted in the deposition of a widespread sand unit which was subsequently subaerially exposed. Rift-related tectonism ceased by Middle Jurassic time when subsidence/eustatic changes resulted in more open marine conditions and the consequent deposition of limestones across a broad platform. Lowered sea level resulted in a dramatic seaward shift in the limit of clastic sedimentation.

By the middle of the Late Jurassic, ocean basin subsidence relative to the continental margin had progressed to the point where a distinct shelf edge was formed. The shelf edge provided a structural root for subsequent biohermal development. The carbonate bank buildup persisted until some time in the Early Cretaceous when it ceased, probably because of eustatic and/or climatic changes. This shelf edge complex, including the carbonate bank buildup, is discontinuously distributed in the subsurface and trends parallel to the present shelf break throughout the planning area. Sea level has remained near its present level. Hence, Cretaceous and Tertiary sediments are predominantly sands, shales, and siltstones.

Petroleum Potential

Exploration for petroleum in the Georges Bank Basin began in April 1976 when the first of two Continental Offshore Stratigraphic Test (COST) wells was spudded. Eight additional wells were drilled by industry in 1981-82, all of which were dry. The North Atlantic planning area can be divided into three areas of hydrocarbon potential. These areas are: (1) the Gulf of Maine, (2) the Georges Bank Basin (a zone of thick sediments centered on, and approximately parallel to the modern shelf break), and (3) the deepwater area seaward of the continental slope. Because of limited geological and geophysical data, the petroleum potential of the Gulf of Maine and deepwater areas is not well known. The most prospective part of the planning area is the zone of thick sediments centered below the present shelf edge. This area includes the Jurassic paleoshelf edge carbonate buildup. The buildup in the Georges Bank area has not yet been drilled. Samples from the equivalent strata to the northeast (Scotian Shelf) have reasonably good porosity and permeability, and show evidence of hydrocarbons. Traps associated with the buildup include anticlines shoreward of the buildup, stratigraphic traps, and fault closure. The zone of thickest sediment also includes some diapiric deformation which trends southwest from the Canadian border.

Potential source and reservoir rocks in a number of the wells drilled on the shelf have been analyzed. Source rock quality is in the poor to fair range. Most of the kerogen is of terrestrial origin and, thus, is considered gas prone.

Reservoir rocks in the thermally mature interval of the section tend to be tight with porosity ordinarily less than 5 percent. Sandstone as a distinct lithology is largely absent in the thermally mature interval throughout most of the zone of thick sediments. Potential reservoir lithologies thus appear to be limited to limestones with secondary porosity development.

Mid-Atlantic

Regional Geology

The Baltimore Canyon Basin is the major geologic feature of the Mid-Atlantic Planning Area. The basin is an elongated northeast trending depression averaging 125 miles (200 km.) in width and extending some 400 miles (640 km.) in length. Sediment thickness in this basin exceeds 50,000 feet (15,200 m.) and the sediments range in age from Triassic to Holocene with most of the section being of Jurassic age.

Rifting began in Triassic time and produced subbasins floored by graben blocks. These subbasins were filled with clastic, volcaniclastic, evaporitic, and lacustrine sediments. This sedimentary sequence was partly eroded and then, as sea level rose, was overlain by a younger Triassic coastal sedimentary sequence.

Rift-related tectonism ceased by Lower Jurassic time and the postrift encroachment of marine waters resulted in deposition of shallow water, oolitic limestones interbedded with marginal marine clastics and swamp deposits in a shoreward direction.

During the Jurassic, the structural configuration of the shelf and the basin itself developed, and the shelf edge became a locus for biohermal growth which ended in the Early Cretaceous, probably due to climatic or eustatic changes. In the subsurface of the Baltimore Canyon area the carbonate buildup is conspicuously missing. Rapid sedimentation and/or extensive faulting has precluded or masked the development of this feature.

Salt deposition, probably near the beginning of the postrift phase followed by loading with younger sediments, resulted in scattered occurrences of deep-seated diapirism. Other scattered intrusives are sparsely distributed throughout the planning area; one of the largest of these, the Stone Dome, is believed to be an igneous plug.

Cenozoic sediments are predominantly poorly consolidated sands, mudstones, clays, and marls deposited in shallow water. Relatively deep, open marine conditions prevailed for most of the Eocene and resulted in the deposition of a thick sequence of limestones that grade into marls and calcareous mudstones in a landward direction. Surface sediment is mostly sand and unconsolidated mud.

Petroleum Potential

The first deep stratigraphic test well (COST B-2) in the Mid-Atlantic Planning Area was drilled in 1976. COST B-3 was completed in 1979 and was followed by 32 industry exploratory wells. Except for five wells drilled on a single large structure (the "Texaco-Tenneco structure"), which discovered significant quantities of gas and condensate, all the industry wells failed to encounter significant hydrocarbons. The COST B-3 well, located about 30 miles southwest of the "Texaco-Tenneco structure," encountered a show of gas from a 6-foot zone below 15,000 feet (4,500 m.).

Among the most prospective parts of the Mid-Atlantic Planning Area is the zone of thick sediments beneath the modern continental shelf area. The carbonate buildup and associated fore- and back-buildup traps are considered part of this zone. Several wells drilled in this trend were plugged and abandoned.

Potential source and reservoir rocks in a number of wells have been analyzed. Source rock quality is generally in the poor to good range. Much of the kerogen is terrestrial in origin indicating most of the generated hydrocarbons would be gas rather than oil. Presumably, the potential for oil would increase seaward where the proportion of algal, oil-prone kerogen would be expected to increase, but in the sedimentary section in the Baltimore Canyon Basin that is considered thermally mature for hydrocarbon generation, the source rock shales tend to be lean in organic matter (usually less than 1 percent).

Reservoir rocks below 10,000 feet (3,000 m.) are limited to sandstones with relatively low porosity and permeability. Some development of secondary porosity by dolomitization of limestones has been observed but is considered only of local significance. Well log interpretations show that only a small fraction of the total sand thickness below 10,000 feet (3,000 m.) has porosities greater than 5 percent. Permeability is low because of infilling of intergranular voids by calcite cement and by clay-silt sized sediment.

South Atlantic

Regional Geology

The South Atlantic Planning Area consists of three major basins: the Southeast Georgia Embayment, the Carolina Basin, and the Blake Plateau Basin.

The Southeast Georgia Embayment is an east-plunging depression approximately 120 miles (190 km.) long and 80 miles (130 km.) wide in which the sedimentary section rarely exceeds 10,000 feet (3,000 m.) in thickness. Although most Atlantic OCS exploration targets are of Jurassic age, sediments of Jurassic age are absent in this basin. The lower, thermally mature part of this basin is largely composed of Cretaceous continental clastics with poor source rock characteristics. These sediments rest unconformably on Paleozoic basement. Sediments are flat lying (marine deposits) and include few large structural traps.

The Carolina Basin, which includes the Carolina Trough, is approximately 225 miles (360 km.) long and 150 miles (240 km.) wide and contains, along its axis, over 30,000 feet (9,100 m.) of sedimentary fill. This basin has not been drilled, but seismic correlations suggest that the rocks range in age from Triassic (?) to Holocene with most of the sediments being of Jurassic age. Triassic (?) sediments are probably continental clastics deposited prior to ocean basin rifting. Jurassic rocks are probably limestones and dolomites with clastic interbeds. The carbonates either grade landward into clastics or pinch out entirely. Cretaceous and younger sediments are believed to be mostly sand and shale with carbonates occurring as a second order component in clastic rocks, e.g., marls and calcareous mudstones.

The Blake Plateau Basin is the largest sedimentary basin off the U.S. East Coast, approximately 320 miles (515 km.) long and 175 miles (280 km.) wide. There are no exploratory wells in the basin but speculations regarding the probable lithologies have been made based on seismic facies analysis and peripheral Deep Sea Drilling Project (DSDP) well data. Most of the basin is thought to be floored by transitional basement generated during the rifting process. Sediments above basement are mostly limestones and dolomites which are over 30,000 feet (9,100 m.) thick in the axis of the basin. More than half the total thickness is Jurassic in age with most of the remainder being Cretaceous; the Tertiary section is extremely thin. The surface of the Blake Plateau is presently swept by strong bottom currents that inhibit significant sediment accumulations.

Petroleum Potential

The petroleum potential of the South Atlantic Planning Area is difficult to assess, largely due to the lack of exploratory well data. The first deep well in the planning area was the COST GE-1 well completed in 1977 in the Southeast Georgia Embayment. This was followed by six unsuccessful exploratory wells, also drilled in the Southeast Georgia Embayment in 1979.

The Carolina Basin appears to have good potential for hydrocarbon generation and entrapment. It has sufficient sediment thickness to ensure an interval of thermal maturity, it has large numbers of attractive traps, and the section may include oil-prone source rocks. A thick regional salt bed, deposited immediately after rifting ceased, has been deformed by sediment loading and produced a number of diapirs on the seaward edge of the basin. A growth fault on the continental slope associated with salt flow may have produced other traps. Other faults are common within and on the margins of the basin.

The Blake Plateau Basin may have attractive possibilities for commercial accummulations of hydrocarbons. The basin is large in area, contains thermally mature sediments, and the section is probably totally marine, indicating source rocks may be oil-prone due to the presence of algal kerogens. The sediments appear unaffected by faulting or deformation suggesting that the basin has been tectonically stable since Lower Jurassic time. The few structures that exist are areally large but of very low relief. There is also evidence of a carbonate buildup trend.

Straits of Florida

Regional Geology

The Straits of Florida area consists of the offshore portion under U.S. jurisdiction of the southern half of the Florida Peninsula, Florida Keys, Bahamas, and northern Cuba. This contains part of the Blake Plateau Basin and the eastward extension of the South Florida Basin. The South Florida Basin encompasses an area of approximately 75,000 square miles (147,600 sq. km.) from the Florida Escarpment in the Gulf of Mexico to approximately 79° west longitude in the Atlantic. Data availability preclude an extension of this basin further into Bahamian waters.

Sediment thickness is variable throughout the region to a maximum of about 35,000 feet (10,700 m.). The dominant sediment type of the Straits of Florida area is carbonate. The post-Triassic section is almost totally chalks, limestones, dolomites, and unconsolidated lime muds of shallow water origin. Evaporites and chert are important secondary lithologies. Triassic (and perhaps Lower Jurassic) rocks are arkosic sandstones and volcaniclastics which were deposited above grabens and half grabens and, as a consequence of rifting, developed in Paleozoic/Mesozoic crystalline basement. These rocks are separated from the overlying Jurassic and younger carbonates by a prominent regional unconformity.

Petroleum Potential

Commercial hydrocarbon accumulations have not been discovered in the Florida Straits region, but minor production occurs in areas peripheral to the region (northwest coast of Cuba and Sunniland Field in Florida). These small fields produce from carbonate reservoirs, and the oil and gas may have originated from carbonate source rocks. Wells drilled in Bahamian waters indicate that much of the section has been flushed by circulating water. This has resulted in locally excellent porosity (occasionally cavernous) but also appears to have driven out any in-situ hydrocarbons. Petroleum potential may exist in the deeper parts of the section where limestone has been altered to dolomite resulting in significant secondary porosity development. Deposition of evaporites in the Jurassic does not appear to have resulted in large numbers of diapiric structures with which hydrocarbon accumulations could be associated.

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Eastern Gulf of Mexico

Regional Geology

The Eastern Gulf of Mexico (EGOM) Planning Area lies offshore from the States of Alabama and Florida. Physiographically the area is mainly underlain by the West Florida shelf and escarpment, which constitute the Florida carbonate platform, and is composed of a thick Mesozoic-Cenozoic sequence of primarily carbonate bank deposits. The western margin of the area consists of the terrigenous clastic province of the Northwest Florida (Alabama/Florida) shelf, DeSoto slope, and Mississippi Fan. Average sediment thickness for the entire planning area exceeds 25,000 feet (7,600 m.).

Potential hydrocarbon plays in the northwest portion of the EGOM are primarily in extensions of Jurassic and Cretaceous trends from the north. The Destin Anticline is a large (12 x 50 mile [20 x 80 km.]), northwest-southeast trending structure formed over a salt swell. It is within an embayment that extends across the Florida Panhandle, the Northwest Florida shelf and slope, and into the deep waters of the DeSoto Canyon. The Suwanee Basin is the more easterly portion of this feature, extending in a northeast-southwest direction.

The DeSoto Canyon slope, in the northwestern part of the EGOM, is underlain by a thick sequence of sediments folded and arched by isolated salt domes and pillows.

The Mississippi Fan is a broad, thick arcuate accumulation of Pleistocene, shallow-water sediments extending nearly 375 miles (600 km.) from the Mississippi Delta to the abyssal plain. It covers an area greater than 111,970 square miles (290,000 sq. km.) and totals 14,765 feet (4,500 m.) in its thickest portion. It consists of a series of coalescing fan lobes with thick sand sequences present.

The Middle Ground Arch is a northeast-southwest trending high lying between the Suwanee Basin and the Central Florida Trough. The Central Florida Trough is a mildly negative saddle located next to the basement high adjacent to the South Florida Basin. It contains more than 16,400 feet (5,000 m.) of pre-Middle Cretaceous sediments.

The South Florida Basin encompasses an area of about 75,000 square miles (147,636 sq. km.) and extends, in the Gulf, from the Peninsula Arch on the east to the Florida Escarpment on the west. The basin appears to extend into the Atlantic.

The West Florida Escarpment extends from the DeSoto Canyon slope south to the Florida Straits. The escarpment is a constructional slope built up of shelf edge carbonate deposits and reef growth during Early Cretaceous time. Samples from the area show a lack of high energy facies indicating that the escarpment is an erosional feature. Limestones and deep water chalks ranging in age from Late Cretaceous through Pleistocene unconformably overlie older, shallow-water carbonates.

Petroleum Potential

The EGOM is primarily a carbonate province. Exploratory drilling commenced in 1974, and there have been no commercial discoveries to date. There is production onshore in the South Florida Basin from the Lower Cretaceous Sunniland Formation. Eleven oil fields have been discovered in this basin on the Florida mainland. The fields are associated with magnetic highs and noses on the northeastern rim of the basin. Production occurs between 11,320 and 11,890 feet (3,450 and 3,620 m.). The offshore part of the basin has not been fully tested but may be prospective. Production also occurs in the Florida Panhandle from Jurassic sediments.

Source rocks in the EGOM are predominantly marine shales and organic-rich carbonates ranging in age from Jurassic to Cretaceous. Cenozoic rocks may be important sources in deeper water. Tertiary sediments do not appear to have a promising suite of source rocks. Reservoir rocks range in age from Jurassic to Cretaceous. Jurassic reservoir rocks are primarily grain-supported wakestones, packstones and grainstones, and dolomites. Prospective Cretaceous reservoir rocks are deltaic and turbidite sandstones, carbonate reefs developed on the landward side of uplifted blocks, and shell zones. Many potential traps exist in the EGOM including anticlines and faulted anticlines, structural closure against normal and growth faults, and a variety of stratigraphic and reef traps.

Specifically, in the area of the Destin Anticline on the northwest Florida shelf, several dry holes have been drilled but excellent reservoir rocks were found in the

Norphlet Formation (Lower Jurassic), and the structure still has potential. There is a field of salt diapirs (DeSoto Diapir Field) located southwest of Destin that has not been tested and which may have hydrocarbon potential.

Regional growth faults parallel the shelf edge in the DeSoto Canyon area and may contain traps on the downthrown side. Peripheral and radial faulting associated with salt structures may contain potential traps. Structural and stratigraphic traps in Jurassic strata, onlapping Paleozoic metamorphic rocks around the edge of the Middle Ground Arch, are possible exploration targets. Potential targets in the Central Florida Trough are structural and stratigraphic traps in Jurassic and Lower Cretaceous strata onlapping Paleozoic igneous and metamorphic rocks.

Central Gulf of Mexico

Regional Geology

The Central Gulf of Mexico (CGOM) Planning Area encompasses the continental shelf off the Louisiana coast, the area east of the Mississippi Delta off the Mississippi and Alabama coasts to the eastern edge of Mobile Bay, and the deeper water areas of Mississippi Canyon, Atwater Valley, Green Canyon, and Walker Ridge. The area is largely a Mesozoic-Cenozoic basin with a series of thick Cenozoic depocenters which have shifted seaward with time to a Pleistocene depocenter at the shelf edge. The geologic province of the CGOM is composed of a thick sequence of clastic sediments deposited in offlapping wedges that have been deformed by the movement of salt and undercompacted shale during Cenozoic time.

Structural deformation in the Gulf of Mexico since mid-Cretaceous time has been primarily in response to heavy sediment loading. Mesozoic and Cenozoic sediments have been upwarped, folded, and penetrated by diapiric structures created by the plastic flow of thick Jurassic Louann Salt deposits. Large contemporaneous growth faults are also major structural features of the CGOM. Peripheral and radial faulting are typically associated with diapirism. In some areas undercompacted shales have deformed plastically in a manner similar to the salt and are responsible for some of the mounding and diapirism in various locations.

Older Mesozoic trends occur in the Late Jurassic which extend across southern Mississippi and Alabama and into State waters near Dauphin Island, Alabama. These trends dip and continue southeastward into the Federal Outer Continental Shelf (OCS). Prospective Lower Cretaceous trends extend from Texas to southwestern Alabama and probably occur under the OCS off Mississippi and Alabama in the form of deltaic and turbidite sandstones, carbonate reefs, and shell zones. Upper Cretaceous sands extend in a band across south Louisiana and may extend southeastward across the eastern Louisiana/Mississippi continental shelf and slope.

Throughout Cenozoic time clastic sediments poured into the Gulf of Mexico Basin from the north and west. There are five major producing trends in the CGOM: Lower Miocene, Middle Miocene, Upper Miocene, Pliocene, and Pleistocene. Prior to the Miocene the major source of sediment supply was from the west, carried by the ancestral Rio Grande and

Brazos River systems. As the major supply of sediment shifted to the north, and the Mississippi River system became the major sediment carrier the major depocenters also shifted to the northern rim of the Gulf. There was a gradual southward shift of depocenters during the Lower, Middle, and Upper Miocene. The maximum accumulated sediment thickness exceeds 20,000 feet (6,100 m.). Pliocene sediments were also deposited in a deltaic environment and attained an aggregate thickness of 8,200 feet (2,500 m.).

The Pleistocene depositional environment was similar to the Miocene/Pliocene. Although numerous small transgressions and regressions occurred, in general, regression prevailed. There was a large increase in sediment supply from the glaciated areas to the north. The Pleistocene depocenter lies along the shelf edge south of Louisiana where 15,000 feet (4,750 m.) of Pleistocene sediments have been drilled. Total thickness may exceed 20,000 feet (6,200 m.).

Many large structures occur on the continental slope which forms the southern part of the CGOM. The area is underlain by Pleistocene and Pliocene sediments and the structures are most certainly salt domes.

Petroleum Potential

The CGOM has 441 oil and gas fields which range in age from Miocene to Pleistocene. Source rocks for the CGOM consist primarily of organic-rich shales which range in age from Lower Cenozoic through Pleistocene. However, potential Mesozoic source rocks occur in the CGOM east of the Mississippi Delta. East of the delta, reservoir rocks in the CGOM range in age from Jurassic through Cretaceous while reservoir rocks in the CGOM, south of Louisiana, consist primarily of sands ranging in age from Miocene to Pleistocene. The producing horizons become progressively younger in age in a seaward direction. Types of traps include anticlines and faulted anticlines formed by deep-seated salt and shale ridges, salt and shale domes and salt massifs, and structural closure against normal and growth faults. Stratigraphic traps include sands onlapping salt and shale domes and anticlines, and facies changes from sands to impermeable shales in updip directions and at angular unconformities.

In the portion of the CGOM east of the delta, prospective traps occurring in the Jurassic and Cretaceous include updip sections where sands or porous carbonates pinch out or truncate updip, anticlinal structures developed on the downthrown sides of growth faults over deep-seated salt domes and pillows, and very subtle fault closures.

The oldest producing Cenozoic horizon in the CGOM is Lower Miocene. Miocene production extends from east of the Mississippi Delta into the Western Gulf of Mexico (WGOM) Planning Area. Production is primarily from deltaic sands.

Pliocene production extends from east of the Mississippi Delta into the High Island area in the WGOM Planning Area. Pliocene production also continues beneath the Pleistocene in a Pliocene/Pleistocene producing trend.

Pleistocene production extends from the shelf edge south of Louisiana into the WGOM Planning Area on the continental slope. Pliocene and Pleistocene production has already been established at several locations in water depths approaching 3,280 feet (1,000 m.). Pleistocene production will probably exceed all other producing horizons.

Two major exploration trends include the Jurassic Norphlet play and the Pliocene/Pleistocene deep-water flexure trend. The Norphlet is a deep gas play [20,000 feet (6,100 m.)] of eolian sands in the Mobile Bay area. The flexure trend extends along the Louisiana-Texas continental slope in which deep-water salt acts as dikes against Pliocene/Pleistocene sands. Reservoirs occur below 9,000 feet (2,700 m.) in depth.

Western Gulf of Mexico

Regional Geology

The Western Gulf of Mexico (WGOM) Planning Area includes the entire Texas shelf and slope, including the deep-water areas of Corpus Christi, Port Isobel, East Breaks, Alaminos Canyon, Garden Banks, and Kiethly Canyon. This area is primarily an Early Cenozoic depocenter although Paleocene and Eocene strata are very deep. Sedimentation continued throughout the Cenozoic, but the sediment supply was far less than in the Central Gulf of Mexico (CGOM) Planning Area.

Structurally the WGOM has been subjected to essentially the same tectonic forces that shaped the CGOM. However, in contrast to the dominantly deltaic depositional environment of the CGOM, the WGOM is characterized by regional down-to-the-basin fault systems with rollover into the faults and linear sands deposited in offshore bar facies. Masses of undercompacted shales have flowed into ridges, swells, and diapirs similar to the salt structures in the CGOM. Louann Salt deposits of Middle to Late Jurassic extend beneath the Texas-Louisiana shelf and along the continental slope southerly into Mexican waters.

During the early Tertiary, the primary supply of sediment to the Gulf of Mexico Basin came from the west and was transported by the ancestral Rio Grande and Brazos River systems. This is indicated by the presence of major depocenters in the Houston and Rio Grande Embayments. The potential for Paleocene strata occurring in the WGOM is very low because the main depositional area lies well inland from the WGOM. Eocene deposits grade from lower axial sediments onshore into bathyl sediments in the WGOM and are extremely deep and marginal. Studies indicate that Oligocene turbidites and deep sea fan deposits may be present in the present day shelf region. Lower Miocene sands in the WGOM consist mostly of regressive sands interfingering with marine shales and may be as much as 5,000 feet (1,520 m.) thick on the South Texas shelf. Several small deltas were formed in the Upper Miocene in the Rio Grande Embayment. However, because of a narrow shelf, favorable conditions for large accumulations of sand apparently did not exist. There is a perceived lack of good quality reservoir rocks in the Miocene in the southern part of the Texas shelf. Turbidity currents and submarine channels could have transported coarse and fine-grained sediments into deeper waters. There may exist, therefore, a Miocene potential in the deeper waters off South Texas. The Pliocene, in general, was subjected to the same type of depositional regime as the Miocene. Pliocene production occurs in the High Island portion of the WGOM but is less productive than off Louisiana because of a lesser sediment supply. The Pliocene has a maximum thickness of about 4,000 feet (1,200 m.) in the WGOM.

The Pleistocene sequence is exemplified by large quantities of sand deposited under dominantly marine conditions. Although punctuated by minor transgressions, it was dominantly a regressive period.

Petroleum Potential

Though not as rapidly, petroleum development in the WGOM has progressed somewhat in parallel with that in the CGOM. There are 142 producing fields in the WGOM and 84 of them are in the Galveston and High Island areas at the northern end of the WGOM. Production extends as far south as North Padre Island where there are five fields. Exploration and discovery have, in general, progressed from north to south and eastward into deeper water.

Source rock consists chiefly of organic-rich, Cenozoic shales. Studies indicate the possibility of Oligocene reservoir rocks in deeper waters. Miocene reservoirs extend the length of the WGOM in a narrow inshore band which widens to the northeast. There are Pleistocene reservoirs in the northern part of the WGOM which extend to the southern part of the Galveston area and which contain accumulations of gas and condensate in the High Island area. Trapping mechanisms are the same as those in the CGOM except that traps associated with rollover into growth faults are more prevalent and there is less salt diapirism. Numerous anticlinal shale ridges also provide structures for traps.

Eocene production is onshore, mainly from lower axial portions of the embayments on the Texas coastal plain. There is no apparent Oligocene production; however, Oligocene turbidites may be potentially productive.

Exploration trends include the westward extension of the flexure trend into the East Breaks deep-water area and the Corsair trend. This play involves a 100-mile listric growth fault with an anticlinal rollover feature trending northeast-southwest through the Brazos, Matagorda Island, and Mustang Island areas. The productive sands are Middle Miocene in age deposited in a deltaic environment. Prospective objectives are as deep as 16,000 to 18,000 feet (4,900 to 5,500 m.).

Southern
California

Regional Geology

The Southern California Planning Area extends northward from the United States-Mexico Provisional Maritime Boundary to the offshore extension of the county line between San Luis Obispo and Monterey counties. The area contains a large part of the offshore Santa Maria Basin, the Santa Barbara Channel, which is the offshore extension of the Ventura Basin, and numerous basins, banks, and depocenters in the southern California continental borderland.

The Santa Maria Basin is part of the Coast Range geomorphic province. The basin extends northward, from Point Conception, to approximately 36° 15' north latitude. The offshore portion of the basin is approximately 140 miles (225 km.) long and 25 miles (40 km.) wide. It is separated from the Santa Barbara Channel to the south by truncated edges of Paleogene sediments. The Santa Barbara Channel is part of the Transverse Range geomorphic province. The Channel lies between the mainland, from Point Conception to Point Hueneme, and the Channel Islands and is approximately 90 miles (145 km.) long, varying in width from 32 miles (52 km.) to about 12 miles (20 km.). The southern California continental borderland is part of the Peninsular Range geomorphic province. The Santa Cruz/Catalina Ridge divides the inner basins from the outer basins.

In the offshore Santa Maria Basin, Middle and Late Neogene sediments overlie Cretaceous and older sediment and metamorphic rocks. Remnants of Early Paleogene sediments have been preserved in some of the low areas of the basin. Neogene sediments exceed 10,000 feet (3,000 m.). Structural trends are generally northwest-southeast.

Sediments in the Santa Barbara Channel include a thick section of pre-Neogene marine and nonmarine clastic rocks overlain by a sequence of Neogene sandstones, shales, and fine-grained siliceous rocks which thickens toward the northeast. In this area sediment thickness exceeds 20,000 feet (6,100 m.). Structural trends are generally east-west.

The stratigraphic sequence in the basins and on the banks of the southern California continental borderland is varied. In the nearshore areas some of the basins contain only Paleogene and Early Neogene sediments; others contain only Middle and Late Neogene sediments overlying metamorphic basement rocks.

Banks farther from shore generally have Paleogene and Late Cretaceous sandstones and shales overlying metamorphic basement. These rocks are in turn overlain by Neogene sediments in the basins. The outermost basins and banks, however, have Neogene sediments lying on basement rocks. The structural trend in the borderland is generally northwest-southeast. Total sediment thickness, in certain places, for the southern California borderland, could exceed 10,000 to 20,000 feet (3,000 to 6,000 m.).

Petroleum Potential

While oil production commenced off of southern California in 1896 with the development of the Summerland Field in State waters, exploration began in Federal waters in the Santa Maria Basin in 1964 with the drilling of exploratory wells following the first Pacific oil and gas lease sale in May 1963. Twelve fields are located in the onshore portion of the basin with development activity about to commence in the offshore portion. One COST well was completed in 1978.

Thirteen fields capable of commercial production have been discovered in the Santa Barbara Channel in Federal waters since the advent of drilling there in 1967. Six fields are currently on production.

Two oil fields have been discovered in San Pedro in the inner banks area of the southern California borderlands. One COST well, drilled in 1975, and nine exploratory wells, commencing in 1976, have been drilled in the outer banks area.

The primary reservoirs in the Santa Monica and San Pedro Basins and the northeastern Santa Barbara Channel are sandstone beds of Middle and Early Pliocene and Late Miocene ages, as is the case in their onshore counterparts, the Los Angeles and Ventura basins. Miocene sandstones and fractured fine-grained Monterey siliceous and calcareous reservoirs are the primary targets in most of the southern California continental borderland, in the southern and western Santa Barbara Channel, and in the Santa Maria Basin. Paleogene sandstone reservoirs are additional targets in the Channel and in the outer basins. While Miocene shales, especially the highly organic shales included in the Monterey Formation, are the major source rocks of petroleum in southern California, Pliocene and Paleogene shales may also be source rocks.

Central California

Regional Geology

The Central California Planning Area includes the region between the offshore extension of the San Luis Obispo/Monterey county line and the offshore extension of the Sonoma/Mendocino county line. The northern portion of the Santa Maria offshore basin, (sometimes referred to as the "Partington Basin"), the Año Nuevo (Outer Santa Cruz) Basin, the La Honda (Inner Santa Cruz) Basin, and the Bodega Basin are located within the planning area. The planning area is in the offshore portion of the Coast Range geomorphic province and structural folds and faults trend northwest-southeast approximately parallel to the basin trends.

The Año Nuevo Basin extends northwest from the Monterey Peninsula to the base of the continental slope. It is approximately 75 miles (120 km.) long and 21 miles (35 km.) wide. The basin plunges to the northwest. Sediment thickness approaches 8,000 to 12,000 feet (2,400 to 3,650 km.).

The La Honda Basin extends from east of Monterey Bay onshore, northwestward offshore of San Francisco. The northwest boundary where it adjoins the Bodega Basin is undefined. The basin is approximately 90 miles (145 km.) long and 12 miles (20 km.) wide. Sediment thickness may exceed 15,000 to 20,000 feet (4,500 to 6,000 m.) in parts of the basin.

Bodega Basin may be an extension of the La Honda Basin. It is bound by a high on the west (Farallon High), the San Andreas Fault along the coast on the east, and a poorly defined uplifted area at the south end of the Point Arena Basin to the north. The basin is about 110 miles (180 km.) long and averages 15 miles (25 km.) in width. Neogene strata are as much as 13,500 feet (4,100 m.) thick.

Distribution of Paleogene and older sediments in the basins of the planning area varies considerably. In the Partington Basin, and Año Nuevo Basin to the northwest, Paleogene strata appear to be absent. Late Cretaceous sediments underlie the Miocene sediments and volcanics of the Año Nuevo Basin. The onshore La Honda and Bodega Basins, however, contain Paleogene sediments, although Late Paleogene sediments in the Bodega Basin are absent due to erosion.

In contrast to the Paleogene, Neogene sediments are widely distributed over the basins included in the planning area. In the Partington Basin, the Monterey Formation apparently rests on basement rocks, but in the Año Nuevo Basin a thick section of Monterey rocks overlies Early Neogene sediments and volcanics. Early to Late Neogene sediments and volcanics are present throughout the La Honda and Bodega Basins, although Late Miocene erosion removed much of the Monterey Formation in some portions of the Bodega Basin. Organic-rich, fine-grained calcareous and siliceous rocks of the Monterey Formation are present in all the basins located within the planning area. In the basins, rocks of the Monterey Formation are overlain by varying thicknesses of Late Neogene mudstone, shale, and minor amounts of sandstone.

Petroleum Potential

Ten wells were drilled in the Bodega Basin, beginning in 1963, and two wells were drilled in the Año Nuevo Basin, beginning in 1967, on leases issued in the 1963 OCS lease sale. In both Año Nuevo wells, drill cuttings throughout the nearly 3,000 feet (900 m.) of Monterey Formation were coated with free tarry oil, but no drillstem tests were run. Oil shows were encountered in six of the Bodega Basin wells, one of which was tested, resulting in the recovery of only drilling mud and water.

Some of the earliest oil and gas production in California (circa 1880) came from onshore fields adjoining the Central California Planning Area. The size and number of the fields discovered, however, proved to be small and the ultimate production from them will probably be less than 10 million barrels of oil and 10 billion cubic feet of gas. Production was derived from reservoirs of Eocene through Pleistocene age.

While the primary source and reservoir rocks in the basins within the planning area are in the Monterey Formation of Middle and Late Miocene age, additional potential hydrocarbon sources and reservoirs exist in the shales and sandstones of the younger and older rocks of the sedimentary section. The basins are oil prone.

Northern California

Regional Geology

The Northern California Planning Area includes the region between the offshore extension of the Sonoma/Mendocino county line and the offshore extension of the California/Oregon border. Within the planning area are two offshore basins: the Point Arena Basin, extending from Point Arena to Punta Gorda, and the Eel River Basin, extending from Cape Mendocino onshore to Cape Blanco offshore in southern Oregon. Both are part of the Coast Range geomorphic province.

The Point Arena Basin is approximately 105 miles (170 km.) in length and varies in width between 18 miles (29 km.) in the south and 33 miles (53 km.) in the north. In the basin, Paleogene sediments are found lying unconformably on pre-Tertiary basement rocks. Erosion has removed younger Paleogene rocks and the remaining Paleogene sediments are overlain by a thick section of Neogene rocks whose age varies from Early Miocene through Quaternary. Neogene sediments attain a thickness of as much as 12,000 feet (3,650 m.).

The offshore Eel River Basin extends from just south of Eureka into southern Oregon for approximately 125 miles (200 km.). Its width is approximately 12 miles (20 km.). Basement rocks in the Eel River Basin are metamorphic "Franciscan" rocks and sedimentary rocks of Cretaceous and early Paleogene age. They are separated from overlying Late Neogene sediments by a major unconformity. Data from onshore wells indicate that Neogene thickness ranges from 5,900 feet (1,800 m.) to more than 11,500 feet (3,500 m.).

Structural trends in the planning area are northwest-southeast to north-south, parallel to the alignment of the basin axes.

Petroleum Potential

Three wells were drilled by Shell in 1965-1966 in the Point Arena Basin following the 1963 OCS lease sale. One well, drilled on a tightly folded structure, recovered drill cuttings coated with free tarry oil. In the other two wells, weak oil shows were noted.

The primary source and reservoir rocks in the Point Arena Basin are in the Monterey Formation of Middle and Late Miocene age. Additional hydrocarbon source rocks and potential reservoir rocks exist in the shales and sandstones above and below the Monterey Formation. Oil has been found onshore in Monterey outcrops.

In the offshore Eel River Basin, four exploratory wells were drilled between 1964 and 1965. There were no hydrocarbon shows in any of the wells. Two of the wells encountered sediments from which gas is produced onshore.

Commercial gas has been produced from thin Pliocene turbidite sandstone reservoirs in two fields in the onshore Eel River Basin and minor amounts of high gravity oil have been produced from thin sandstones in Upper Cretaceous rocks near Petrolia, 10 miles (16 km.) south of the Eel River Basin. The Cretaceous rocks plus Lower Paleogene rocks may have contributed gas to the Pliocene and potential Miocene reservoir rocks. Shales of Pliocene and Miocene age may also be source rocks.

Washington - Oregon

Regional Geology

The Washington-Oregon Planning Area includes the region between the offshore extension of the California/Oregon border and the offshore extension of the U.S./Canadian border. Within this area, in addition to the northernmost extension of the Eel River Basin, five basins, in the Coos Bay, Newport, and Astoria areas of offshore Oregon, and in the Willapa and Cape Flattery areas of offshore Washington, make up an elongate trough in which as much as 25,000 feet (7,600 m.) of Tertiary sedimentary and volcanic rocks have accumulated. This trough, lying both onshore and offshore, extends southward from Vancouver Island approximately 400 miles (640 km.) to the vicinity of the Klamath Mountains and from the base of the continental slope eastward to the western edge of the Cascade Range.

In the Eel River Basin, which extends northward from offshore Cape Mendocino in California to offshore Cape Blanco in Oregon, Paleogene rocks are deeply eroded and overlain by Late Neogene deposits with Early Neogene rocks missing. In the Coos Bay area north of Cape Blanco, Early Neogene rocks are absent, but late Neogene rocks overlie a nearly complete Paleogene section. A similar condition exists in the Willapa, Washington offshore area. However, here the Paleogene and Early Neogene sections consist of a melange of Early Miocene, Oligocene, and Eocene sediments called the "Hoh Rocks" or "Hoh River Beds."

Throughout most of the trough, volcanic rocks of Early Eocene age are considered to be economic basement. Neogene rocks, equivalent in age to the Monterey, Rincon, and Vaqueros Formations of southern California, are present in Oregon. The Oregon rocks, however, lack the high organic content necessary for good source rocks of petroleum and the silica content necessary for fracture reservoir production.

Petroleum Potential

A total of 12 wells were drilled in the planning area between 1965 and 1967 following the only OCS oil and gas lease sale in the area held in 1964. Eight wells were drilled off of Oregon and four off of Washington. Of the eight Oregon wells, one tested two gas zones at 50 MCFPD and 70 MCFPD respectively; another encountered shows of oil and gas; and a third recovered samples indicating high gravity crude oil in Late Neogene sediments. Two of the four wells off of Washington encountered hydrocarbons. One well tested 10-20 MCFPD, with shows of oil and gas, and the second well recovered samples indicating medium-high gravity crude oil.

The Mist gas field was discovered onshore in 1979 in the northwestern corner of Oregon. Reservoirs in the field are sandstones of Eocene age. In southwestern Washington, minor amounts of oil have been produced from "Hoh Rocks" of Miocene, Oligocene, and Eocene age in the Ocean City oil field.

Although Monterey-type fracture reservoir rocks are absent in the Washington-Oregon Planning Area, other potential Neogene and Late Paleogene sandstone reservoir rocks are present. Source rocks of adequate richness are also present in the Neogene and Late Paleogene shales.

Volcanic activity, prevalent during much of Tertiary time in the area, has caused many of the sediments to be tuffaceous which results in poor reservoirs.

Shale "pillows" were noted on seismic profiles in the Coos Bay, Newport, and Astoria areas, and elongate shale diapirs penetrating upward to the seafloor were numerous on seismic profiles in the Willapa area.

The potential traps were mapped on the Yakataga and Kulthieth Formations. These traps include large, asymmetric, elongate and doubly plunging, faulted anticlines, and traps against major faults. Nine of these traps have been drilled with no discoveries of oil or gas.

Gulf of
Alaska

Regional Geology

The Gulf of Alaska Tertiary Basin is located in the northeastern area of the Pacific-Margin Tertiary Province. This area extends over 800 miles (1,300 km.) from northeast of Kodiak Island to Dixon Entrance in the eastern Gulf. The offshore part of the province comprises approximately 30,000 square miles (78,000 square km.). The planning area is divided into four physiographically- or geologically-distinctive segments. From east to west, the segments are as follows: the southeastern Alaska segment, from Dixon Entrance to Cross Sound; the Yakutat segment, from Cross Sound to Icy Bay; the Yakataga segment, from Icy Bay to Kayak Island; and the Middleton segment, from Kayak Island to the Amatuli Trough, southwest of Montague Island. The planning area is underlain by Tertiary rocks consisting mostly of clastics, volcaniclastics, and volcanics. These sediments are generally less than 3,200 feet (975 m.) thick in the southeast segment, while they range from 0 to 20,000 feet (6,100 m.) in the Yakutat segment, 10,000 feet (3,000 m.) to over 32,000 feet (9,750 m.) in the Yakataga segment, and from 0 to 12,000 feet (3,650 m.) in the Middleton segment east of Montague Island. West of Montague Island, sediment thickness is less than 5,000 feet (1,520 m.).

The stratigraphy of the Gulf of Alaska is dominated by four formations. The Mesozoic Yakutat Formation is believed to be the top of economic and acoustic basement occurring at shallow depths from Cross Sound to Dixon Entrance. Northwest of Cross Sound, it has a thick covering of Tertiary sediments. Above the Yakutat Formation is the middle Tertiary Kulthieth Formation, consisting of deltaic to deep sea fan deposits and associated volcanics which is seen in two offshore wells in the central Gulf of Alaska. The late Eocene to early Miocene Poul Creek Formation, primarily mudstone and siltstone, is above the Kulthieth and may contain fair source rocks. It is seen onshore and was encountered in four offshore wells. The Pliocene to Pleistocene Yakataga Formation is predominantly glacially derived sediments and is the dominant section penetrated by the unsuccessful wells drilled in the central Gulf.

Petroleum Potential

Offshore drilling commenced in the Gulf of Alaska in 1969 with the drilling of a single well in State waters. Drilling began in the Federal planning area in 1975 with the completion of a COST well. Twelve exploratory wells, including one sidetrack, have been drilled in the planning area since 1976. The only producing field along the Gulf of Alaska, the onshore Katalla Field near Kayak Island, produced oil along a fault zone in the Katalla Formation, a local equivalent of the Poul Creek Formation. Offshore these rocks are a silty shale to shaly siltstone and serve as potential source rocks for petroleum but are not reservoir rocks. The four offshore wells that encounter the Poul Creek Formation all have immature source rocks, and the total organic carbon (TOC) is less than 1 percent and usually 0.5 percent. The Kulthieth Formation may be a good reservoir and possibly another source for petroleum, but this formation was encountered in only two of the offshore wells. The source rocks are mature and have over 1 percent TOC. These source rocks are more prone to have gas than oil. All of the offshore exploratory wells have been drilled into the Yakataga Formation which is a very poor source rock and a fair reservoir rock.

Potential traps have been identified in the Yakataga and Kulthieth Formations and include large, asymmetric, elongate and doubly plunging, faulted anticlines, and traps against major faults.

Lower Cook Inlet/ Shelikof Strait

Regional Geology

This planning area is part of the Alaska Peninsula-Cook Inlet Province which is a topographic lowland that extends from just north of Cook Inlet in a northeast-southwest trend to the tip of the Alaska Peninsula. The province covers an area more than 900 miles (1,450 km.) in length and between 5 to 50 miles (8 to 80 km.) in width.

Rocks of the Lower Cook Inlet are part of a belt of Mesozoic and Cenozoic sedimentary rocks that underlie Upper Cook Inlet on the northeast and the Alaska Peninsula and the Shelikof Strait on the southwest. Along this belt, marine Mesozoic rocks may locally be more than 36,000 feet (11,000 m.) thick, and continental Cenozoic rocks are as much as 25,000 feet (7,600 m.) thick. Sediments are mainly clastic in nature and are grouped into four sequences based on geologic age: Jurassic, Early Cretaceous, Late Cretaceous, and Tertiary. While most subsurface features parallel the general northeast-southwest trend of the basin(s), a notable exception is the east-west trending Augustine-Seldovia Arch in Lower Cook Inlet at approximately 59° north latitude. This arch separates the southern part of the Cook Inlet Basin from the basin which underlies Shelikof Strait. Four major northeast-trending geologic features that flank Cook Inlet are the Alaska-Aleutian Range batholith and the Bruin Bay fault on the northwest side, and the Border Ranges fault and the terrane of undifferentiated Mesozoic and Cenozoic rocks on the southeast side.

Petroleum Potential

Generalized lithologic characteristics have been compiled from 13 exploratory wells drilled between 1978 and 1985 in Lower Cook Inlet and Shelikof Strait and one COST well drilled in 1977 in Lower Cook Inlet. These characteristics were used in evaluating the four ages of rocks for their potential as reservoir rocks and/or source rocks.

The Jurassic rocks were partially penetrated by nearly all the wells to as much as 12,000 feet (3,650 m.). This section is very sandy but it has uniformally low porosity and permeability due to cementation. These rocks have poor reservoir potential.

The Early Cretaceous rocks range in thickness from 0 to 2,500 feet (760 m.). Although this interval has numerous sands, the sands have low porosities and permeabilities. The reservoir potential for the Early Cretaceous is considered to be poor.

Rocks in the Late Cretaceous are both marine and nonmarine. The marine section has from 1,000 to 5,000 feet (300 to 1,520 m.) of siltstone. These rocks have very few sands and the sands have low porosity. In contrast, the nonmarine rocks are sandier, have marginal porosities, and two wells to the north encountered noncommercial quantities of oil. The marine rocks are considered to have poor reservoir potential while the nonmarine rocks have good reservoir potential. The nonmarine section has only been found in the west central part of Cook Inlet.

The Tertiary rocks are Eocene to Paleocene in age. These rocks are from 500 to 5,000 feet (150 to 1,520 m.) thick and their lithology ranges from tuffaceous siltstone to massive conglomerate. This section has low porosity and has very poor reservoir potential.

Kodiak

Regional Geology

The Kodiak shelf is located in the northwestern area of the Pacific-Margin Tertiary Province. It extends southwesterly for approximately 500 miles (800 km.) from the Kenai Peninsula to Chirikof Island southwest of Kodiak Island. The shelf in this area averages approximately 62 miles (100 km.) in width.

The tectonic setting and evolution of the Kodiak shelf have been strongly controlled by the nature and episodicity of interaction between two major crustal plates. Since early Cenozoic time, the Pacific plate has migrated northward relative to mainland Alaska and the North American continent. This differential movement is accommodated at the Aleutian trench where the Pacific plate is subducted beneath the Alaskan continental margin.

Structurally, the Kodiak shelf is mainly a large basin. The landward flank of the basin is a wide zone of faults that separate the subsiding basin from the uplifted block of Kodiak Island itself. The seaward flank is generally an asymmetric arch at the edge of the continental shelf. The shelf contains three subbasins: Tugidak, just north of Chirikof Island, Albatross, on the southwest Kodiak shelf at approximately 153° west longitude, and Stevenson, on the northeast Kodiak shelf at approximately 149° 30' west longitude.

The Kodiak shelf is underlain by two major tectonostratigraphic units. Acoustic basement beneath the shelf is composed of a highly deformed assemblage of flysch and mafic volcanic rocks ranging in age from Paleocene or older to Oligocene. This basement complex is unconformably overlain by up to 25,000 feet (7,600 m.) of gently-deformed shelf sediments ranging in age from Miocene to Holocene. Available seismic data are capable of resolving only coherent, mappable reflectors within or at the base of the younger shelf sequence.

Petroleum Potential

Six deep stratigraphic test wells have been drilled on the Kodiak shelf. Three wells were drilled as part of the Kodiak Shelf Stratigraphic Test (KSST) program in 1976 and three were drilled in the Kodiak Shelf Stratigraphic Drilling (KSSD) program in 1977. In addition, the Tenneco Middleton Island well, drilled some 300 miles

(480 km.) along strike to the northeast, also provides relevant geologic information.

Based upon onshore geology, source rock potential for most rocks underlying Kodiak shelf is poor. Most strata contain less than 0.5 percent (TOC) rendering them marginal potential sources at best. Data from the Middleton Island well suggest that isolated source beds may be present throughout the Tertiary section. These data indicate that structured kerogen predominates, hence these rocks would tend to generate gas rather than oil. Significant exceptions to this pattern are Eocene beds that contain primarily amorphous kerogen that could generate oil rather than gas. Thermal maturity for rocks underlying Kodiak shelf is low, and oil generation, if present, is in the early generation stage; thermogenic gas generation has not yet commenced.

Folds and faults which deform the shelf sequence trend predominantly northeast. These structures are superimposed on larger-scale transverse uplifts. Recognized hydrocarbon traps underlying the Kodiak shelf are simple structures limited to Neogene strata. Trap types include simple folds, fault closures, and unconformity truncations. No regional seals are known to be present but interbedded shales capable of acting as local seals are likely to be present. Due to both their lithology and degree of alteration, reservoir rocks are unlikely to be present in Paleogene strata. However, some reservoir rocks with reservoir-quality porosity and permeability are inferred to be present in Neogene strata. Direct measurements of the porosity and permeability of Miocene and younger sandstones exposed onshore are not available; however, thin Pliocene sands in the Middleton well range up to 18 percent in porosity. Lithologic descriptions of outcrops on Kodiak and surrounding islands reveal that, in general, sediment tends to increase in compositional maturity and in porosity and permeability with decreasing age throughout the sampled part of the Neogene.

Shumagin

Regional Geology

The Shumagin shelf extends along the Aleutian volcanic arc between Chirikof Island and Unimak Pass for a distance of approximately 375 miles (600 km.).

The tectonic setting and evolution of the Shumagin shelf, like the Kodiak shelf, has been controlled by the nature and episodicity of interaction between the two major crustal plates. Since early Cenozoic time, the Pacific plate has migrated northward relative to mainland Alaska and the North American continent. As in the case with Kodiak, this differential movement has been accommodated at the Aleutian trench where the Pacific plate is subducted beneath the Alaskan continental margin.

A shelf-type Mesozoic sequence of volcaniclastic sandstones and siltstones are exposed on the Alaskan Peninsula. To the southeast, the Shumagin Formation of Late Cretaceous age crops out on Sanak and the outer Shumagin Islands. The islands are an uplifted portion of the Shumagin shelf which exposes a deep-water flysch sequence of interbedded sandstone and mudstone which has been intruded by granitic plutons.

Geophysical interpretations extending from off of the Kodiak shelf indicate that two major tectonostratigraphic units underlie the Shumagin shelf. Acoustic basement consists of highly deformed and disrupted sedimentary rocks ranging in age from Paleocene or older to Oligocene. Younger basins, which overlie acoustic basement, contain up to 25,000 feet (7,600 m.) of gently deformed shelf and upper slope sediments ranging in age from Miocene or older to Holocene.

Folds and faults which deform the strata of the upper sequence on the shelf predominantly parallel the axis of the Aleutian trench. The rocks of the Shumagin Islands generally strike northeast, while rocks on the Sanak Islands strike northwest toward Unimak Island and the margin of the Bering Sea shelf beyond.

Petroleum Potential

Preliminary studies of offshore geophysical data indicate the presence of both structural and stratigraphic features which appear capable of entrapping hydrocarbons. However, verification of closure, in most cases, has been tentative due to the low density of the geophysical data.

Normal and reverse faults, along with stratigraphic pinchouts and truncations at unconformities, form potential hydrocarbon traps. To date, there has been no geologic data on the Shumagin shelf to verify the presence of either a potential source bed sequence or a porous reservoir sequence. However, geologic analysis of potential hydrocarbon sources and potential reservoirs from the adjacent Kodiak shelf suggest a low to moderate probability for the occurrence of commercial accumulations within the Shumagin Planning Area.

North Aleutian Basin

Regional Geology

The North Aleutian Basin is a large, sediment-filled, structural depression that underlies portions of both the Alaska Peninsula and the Bering Sea. The basin proper lies north of latitude 55° 45'. This elongated basin trends in an east-northeasterly direction for approximately 240 miles (400 km.) and encompasses an area of about 93,900 square miles (243,200 sq. km.). Approximately four-fifths of the basin's total area is located offshore in water depths of less than 200 feet (60 m.). Asymmetrical in cross section, the basin is bounded on the north by gently dipping basement rock and on the south by a steeply inclined basement ridge. Rocks that form the southern flank crop out in the Black Hills on the Alaska Peninsula.

Sedimentary fill of the basin consists of up to 20,000 feet (6,100 m.) of Cenozoic sediment which is thickest in the southeastern part of the basin. Paleogene formations exposed onshore include, in order of decreasing depth, the Tolstoi, Meshik, and Stepovak. The Tolstoi and Meshik Formations are composed of mostly volcanogenic conglomerate, sandstone, and breccia with some interbedded siltstones. The Stepovak, in addition to volcanic sandstone and conglomerate, also contains thick beds of black siltstone and lignite seams. All three formations are dense and highly indurated. The Bear Lake and the Milky River Formations comprise the Neogene sequence. The Bear Lake is composed of interbedded porous sandstone, conglomerate, and siltstone. The overlying Milky River is composed of conglomerate, sandstone, and mudstone. The Neogene formations and overlying Pleistocene volcanic flows and breccias were deposited in shallow marine to nonmarine environments. Seismic data indicate that all Cenozoic formations continue offshore.

Petroleum Potential

One COST well has been drilled offshore in 1983. Ten exploratory wells were drilled on the Alaska Peninsula. Although a number of oil and gas shows were reported, none suggest a discovery of commercial size. Data from the onshore wells suggest that the most prospective area for hydrocarbons lies offshore between Port Moller and Cold Bay. Geophysical data indicate that this area contains both the thickest Tertiary section and also the most promising anticlinal structures. In addition to this area, there are less promising structures in the southwestern corner of the basin and to the north of Port Heiden. There may also be stratigraphic or fault traps along the southern flank of the offshore extension of the Black Hills uplift. A shallow, flat Tertiary section has discouraged intensive exploration north of 57° latitude.

Data from two onshore wells indicate that the Middle to Late Miocene sandstones of the Bear Lake Formation have the greatest reservoir potential. At a depth of 6,300 feet (1,920 m.), these sandstones have porosities as high as 36.5 percent and permeabilities as high as 1,286 millidarcies (mD). Below this depth the corresponding high values are 29 percent and 43 mD. Shows of oil and gas have been reported from Bear Lake sandstones in both wells and may possibly occur offshore.

The best Tertiary source rocks appear to be the black marine siltstone and shale beds in the Oligocene Stepovak Formation. Analysis of several wells onshore reveals that although thermally immature, the Paleogene strata are rich in organic matter. Offshore, however, these rocks may be more mature due to the greater depth of burial. Other potential source rocks include the basal units of the Bear Lake and Late Jurassic and Late Cretaceous marine shales.

St. George Basin

Regional Geology

The St. George Basin Planning Area lies in the Bering Sea, south of the Pribilof Islands and west of Bristol Bay. Actually, two depocenters for Tertiary sediments occur on the continental shelf in the planning area: the St. George Basin and the Pribilof Basin. The St. George Basin is a graben measuring 10 to 25 miles (16 to 40 km.) wide, extending approximately 200 miles (320 km.) in a northwest-southeast trend, and containing as much as 40,000 feet (12,200 m.) of Tertiary and Mesozoic sediments. The Pribilof Basin is a half graben that is 30 miles (48 km.) wide; it extends approximately 70 miles (113 km.) in a northwest-southeast trend and contains as much as 20,000 feet (6,100 m.) of Tertiary sediments. The shelf area south of the graben to the continental slope contains as much as 10,000 feet (3,000 m.) of Tertiary sediment over mostly sedimentary basement rocks. The area up to within 25 miles (40 km.) north of the graben contains 3,000 to 7,000 feet (900 to 2,100 m.) of Tertiary sediment over igneous basement rock. The remainder of the shelf area has a very thin Tertiary section over igneous basement and is not considered prospective.

Mesozoic rocks encountered along the southeastern margin of the graben ranged in age from Late Jurassic to Early Cretaceous and were mostly fine-grained sandstones with minor shale and coal stringers. They were derived from a volcanic source terrane and deposited in a fluvial to deltaic environment. The Tertiary sediments ranged in age from middle Eocene to Holocene. Dominant lithologies included fine-grained sandstones, siltstones, mudstones, and minor conglomerate. Volcanic rock fragments were common throughout. The sediments were deposited in mostly a marine shelf environment.

Petroleum Potential

Exploration began in the area by 1976 with the drilling of an initial COST well. A second COST well was then drilled in 1982. Ten exploratory wells, including one sidetrack, have been drilled in St. George Basin during 1984 and 1985.

The COST No. 1 well was drilled about 25 miles (40 km.) south of the graben and encountered about 10,000 feet (3,000 m.) of Tertiary sediments overlying the igneous rock basement. COST No. 2 well was drilled along the southeastern margin of the graben and encountered over 12,000 feet (3,650 m.) of Tertiary sediments overlying Mesozoic sedimentary rocks.

Potential traps in the graben include faulted anticlines, upthrown fault traps over basement horst blocks, downthrown fault traps along border faults of the graben, drape of Tertiary strata over basement fault blocks, stratigraphic onlap of Tertiary sediments onto the basement, and possible stratigraphic pinchout of sands. Outside of the graben, potential traps include sub-unconformity truncation below the acoustic basement unconformity, anticlinal structures within the acoustic basement, drape of Tertiary strata over basement highs, fault-bounded traps, and stratigraphic onlap of Tertiary sediments onto basement highs. In the Pribilof Basin, potential traps include anticlines within the acoustic basement with drape in the overlying Tertiary section, upthrown fault traps over tilted basement blocks, and sub-unconformity truncation associated with fault-bounded anticlines.

The best potential reservoir rocks are believed to occur in the Oligocene section. At COST No. 1 well, Oligocene sands attained thicknesses greater than 150 feet (46 m.). Porosities were as high as 25 percent and permeabilities were as high as 37 millidarcies. The volcanic rock fragments tend to reduce porosity and permeability because of diagenetic alteration to zeolites and clay minerals. The Mesozoic sandstones in the COST No. 2 well were very tight.

The source rock potential as indicated by the COST wells appears to be low. The sediments were low in TOC and were deposited under oxidizing conditions. Only gas-prone kerogen types were present in samples from the wells. Vitrinite reflectance data indicated the Tertiary sediments to be immature for oil generation. The "oil window" occurs at approximately the base of the Tertiary section.

The deeper portions of the St. George graben may have better source rock potential than the COST well sites since the basal graben sediments were deposited in an enclosed basin when the area south of the graben, where the COST wells were drilled, was emergent. Restricted circulation in the early stage of graben development may have been conducive to organic preservation. Thermal maturity in the graben may also be more favorable than for the COST well locations since the basal graben sediments are buried more deeply than the lower-most Tertiary sediments at the COST well sites. Therefore, the sediments may have been exposed to high enough temperatures for a sufficiently long time to generate oil. The basal Tertiary section in the Pribilof Basin may also contain favorable source rocks.

Aleutian Basin, Bowers Basin, and Aleutian Arc

The Aleutian Basin, Bowers Basin, and Aleutian Arc Planning Areas encompass various basins that span more than one of these planning areas. In general, these basins are part of the western Bering Sea which is in water depths greater than 10,000 feet (3,000 m.).

Regional Geology (Aleutian Basin)

The Aleutian Basin is generally thought to be floored by Early Cretaceous oceanic crust based on the identification of north striking magnetic anomalies M1 through M13. The crust and lithosphere are thought to be a remnant of the Kula plate which was being subducted beneath the Beringanian margin prior to the earliest Tertiary when subduction shifted southward to the site of the present-day Aleutian Ridge.

Sediments overlying the crust of the Aleutian Basin are approximately 10,000 to 13,000 feet (3,000 to 3,960 m.) thick. The sediments are acoustically well stratified as would be expected for turbidites or other sediments with rapid vertical variations in acoustic impedance. The surficial sediments are flat lying and show no evidence of tectonic disruption. Deeper sediments appear draped over basement topography. A portion of the basin has sediment thicknesses approaching 26,000 feet (7,925 m.). These sediments appear to be folded.

Regional Geology (Bowers Basin)

The Bowers Basin is thought to have formed as a result of back-arc spreading associated with the subduction of the Kula plate beneath the Bowers Ridge. Subduction is thought to have ceased prior to the initiation of subduction beneath the Aleutian Ridge which forms the southern boundary of the basin. Sediments in the abyssal portion of the basin have not been sampled to depths greater than a few meters. Acoustically, they appear to be very similar to those of the Aleutian Basin, i.e., the shallow sediments are flat lying and well stratified; the deeper sediments are less well stratified and drape over basement structures. In general, the basin appears to be floored by oceanic crust and covered by 6,500 to 10,000 feet (1,980 to 3,000 m.) of hemi-pelagic silt and clays.

Regional Geology (Aleutian and Bowers Ridge)

The Aleutian Ridge is a volcanic island chain formed as a result of the subduction of oceanic lithosphere beneath the Bering Sea. The oldest known volcanic rocks on the ridge are roughly 50 million years old and are from Adak Island. Sparse data are available from the Bowers Ridge; however, in the absence of contradictory data, the Bowers Ridge is expected to have had a similar tectonic evolution and, consequently, similar structural features and petroleum potential.

Sedimentary basins are found on the flank of the Aleutian Ridge. For instance, Amlia Basin and Amukta Basin lie on the north flank of the ridge. These basins are grabens or half-grabens and are a result of Cenozoic crustal extension along the crest of the ridge. The basins contain approximately 6,500 to 10,000 feet (1,980 to 3,000 m.) of folded and faulted sediments, the age of which may be as old as middle Miocene. The sediments in these basins are thought to be volcaniclastic sandstones and siltstones.

On the south flank of the Aleutian Ridge sediments have been trapped between an east-striking basement ridge and a summit platform. However, a paucity of seismic data does not allow a determination of basin extent to be made.

Petroleum Potential

Exploration in these basins has been limited to the collection and analysis of multi-channel seismic reflection data and the drilling of some Deep Sea Drilling Project (DSDP) holes (186, 187, 188, and 190) in 1971.

Thick sediment deposits with possible structural traps have been identified in the Aleutian and Bowers Basins and on the Aleutian and Bowers Ridges. Unfortunately the available data suggest that while the sediments in many of these locations are thermally mature, there is probably insufficient organic material in the sediments to generate a sufficient quantity of hydrocarbons to permit migration into the traps. In addition, migration and accumulation would be impeded by the low permeabilities commonly associated with clays, siliceous oozes, and volcaniclastic sediments. This would be particularly true for sediments on the Aleutian and Bowers Ridges, at the base of the Bowers Ridge, and beneath the Bering Shelf rise and slope.

St. Matthew-Hall Basin

Regional Geology

St. Matthew-Hall Basin formed as a crustal sag in the mid-continental shelf of the Bering Sea just west of Bethel and St. Marys. The sag probably formed as a consequence of regional downwarping associated with Late Cretaceous or early Tertiary strike-slip motion of the Kaltag Fault. The basin is filled with less than 6,000 feet (1,830 m.) of layered Tertiary fill. The fill is probably Eocene, Oligocene, and Neogene-age, marine, fine-grained sediments which are overlain by a relatively thin veneer of coarser-grained Quaternary sediments.

Petroleum Potential

There are a few basement-controlled faulted anticlinal structures that occur within 3,000 feet (900 m.) of the surface. Sediments adjacent to the St. Matthew-Hall Basin do not seem to contain significant potential source rocks at depths less than 6,000 feet (1,830 m.) or in rocks younger than the Eocene. Moreover, about 10,000 feet (3,000 m.) of sediments are usually necessary to raise the level of maturity in these basins to the generally accepted threshold of the "petroleum window." This implies that source rocks of at least Oligocene age or older would be necessary to guarantee adequate maturity for petroleum generation. The most likely source of petroleum seems to lie in the Pre-Cenozoic rocks for which there is little available data. If hydrocarbons are discovered in the St. Matthew-Hall Basin, they are most likely to be dry gas deposits. Potential reservoirs are more probable in Cenozoic rocks, but hydrocarbons are more likely to have been generated in the Cretaceous basement, if they occur at all.

Norton Basin

Regional Geology

Norton Basin is a sediment-filled structural depression located in Norton Sound just south of Nome. It underlies approximately 52,000 square miles (130,000 sq. km.) of seafloor.

Structurally, Norton Basin consists of two subbasins filled with more than 14,000 feet (4,270 m.) of layered Tertiary sedimentary rocks. The basin formed as a result of pull-apart tectonics associated with Late Cretaceous or early Tertiary strike-slip motion along the Kaltag Fault. Continental sedimentation dominated Norton Basin prior to the mid-Eocene. Apparently the two subbasins were not formed until the mid-Eocene when the north-trending Yukon horst developed as a common boundary. Until the mid-Oligocene, the horst allowed a shallower marine siltstone and sandstone sequence to be deposited in the eastern subbasin, whereas deepwater clastics were deposited in the western subbasin. Post mid-Oligocene deposition extended beyond the structurally controlled subbasins indicating regional subsidence in response to crustal cooling. This extension unified deposition from late Oligocene to present within the two subbasins. This sequence of rock is mainly Oligocene coals and Neogene shallow-marine siltstones, sandstones, and diatomaceous mudstones.

Petroleum Potential

Exploration began in Norton Basin with the drilling of two COST wells in 1980 and 1982, respectively. The COST No. 2 well encountered shows of gas below a depth of 12,000 feet (3,650 m.). A total of six exploratory wells were completed in 1984-1985.

Anticlines, faulted anticlines, fault traps, and stratigraphic pinchouts are present in the Norton Basin. Faults and unconformities are present to provide migration routes. The major problem facing Norton Basin hydrocarbon production is having a sufficient amount of source rocks with the proper kerogen.

Stratigraphic test well data indicated that sufficient maturity for oil exists below 9,500 feet (2,900 m.) in the western subbasin and 10,600 feet (3,230 m.) in the eastern subbasin. Dry gas and wet gas condensate are most likely. Below 13,000 feet (3,960 m.) there is insufficient organic carbon to serve as a commercial hydrocarbon source. Sandstone porosities of greater than 13 percent and permeabilities of 1 millidarcy are restricted to depths less than 9,000 feet (2,700 m.) (mid-Oligocene or younger) in the eastern subbasin. Sandstone porosities of greater than 24 percent and permeabilities of 1 millidarcy are restricted to depths less than 6,000 feet (1,830 m.) (late Oligocene or younger) in the western subbasin.

Navarin Basin

Regional Geology

The Navarin Basin consists of three en echelon subbasins, here informally named the Navarinsky, Pervenets, and Pinnacle Island subbasins which are filled with more than 36,000 feet (11,000 m.) of layered Tertiary sedimentary rock. The subbasins formed as a result of extensional deformation associated with strike-slip motion or oblique subduction of the Kula Plate beneath the North American Plate in the Late Cretaceous to early Tertiary time. Basin axes trend northwestward and parallel the continental shelf break.

The Pinnacle Island subbasin, the southernmost depocenter, is approximately 45 miles (72 km.) wide and over 170 miles (274 km.) long. It is an asymmetrical graben filled with as much as 36,000 feet (11,000 m.) of Tertiary sediments. The Pervenets subbasin, a symmetrical graben 75 miles (120 km.) long, and 15 miles (25 km.) wide, lies between the Pinnacle Island and Navarinsky subbasins. It contains up to 34,000 feet (10,365 m.) of Tertiary sediment. However, the 26,000 foot (7,925 m.) contour defines the limits of the structurally controlled subbasin topography and above that the Tertiary fill extends beyond the basement topography, thereby linking the Pervenets and Navarinsky subbasins. The northernmost subbasin, the Navarinsky, is more circular, with dimensions of approximately 50 by 70 miles (80 by 113 km.). This deepest subbasin is a graben filled with at least 36,000 feet (11,000 m.) of Tertiary sediments. Like the Pervenets subbasin, the 26,000-foot (7,925-m.) contour defines the limit of the structurally-controlled subbasin. Above 26,000 feet (7,925 m.), the two subbasins can no longer be structurally differentiated.

By the late Eocene, movement of the Kula Plate was isolated by subduction at the Aleutian Arc. Subbasin subsidence, in response to structural downdropping, remained active until the late Oligocene. This allowed the continuous deposition of marine mudstones and siltstones throughout most of the Paleogene. Sea level lowerings in the middle and late Oligocene, however, exposed older Tertiary and Mesozoic basement highs to wave-base erosion which resulted in the deposition of coarser-grained material along the subbasin's flanks. Cessation of Kula Plate motion by the early Neogene was followed by crustal cooling which allowed regional subsidence beyond the structurally defined subbasins. Middle and outer neritic mudstones and sandy mudstones were deposited throughout the Neogene, with a possibility of coarser-grained deposits flanking basement highs that were exposed to wave-base erosion during a sea level lowering in the late Miocene.

Petroleum Potential

Exploration in the Navarin Basin began in 1983 with the drilling of the Navarin Basin COST No. 1 well. Eight exploratory wells have been drilled, all in 1985.

Stratigraphic test well data indicate the late Eocene and early Oligocene mudstones to be the most favorable source rocks in the Navarin Basin. This stratigraphic sequence thickens in the deeper parts of the subbasins, thus possibly providing significant amounts of oil-prone rocks at a favorable level of thermal maturity. Possible reservoir rocks are Oligocene sandy mudstones, basal sands deposited by the early Tertiary transgression over the Mesozoic basement rocks, and coarse-grained deposits flanking basement highs that were deposited during sea level lowerings in the Oligocene and Miocene. Traps found in the basin include anticlines, faulted anticlines, fault traps, and stratigraphic pinch outs. Many traps are adjacent to the potential source rocks; however, traps that are not adjacent may be fed by hydrocarbon migration along unconformities, faults, and through permeable strata. Timing of trap formations and oil generation may provide an important obstacle to oil accumulation in the basin.

Hope Basin

Regional Geology

Hope Basin is a Late Cretaceous to Tertiary sedimentary basin. Its northern limit is defined by a zone of normal faults that parallel the flank of the northwest striking Herald Arch overthrust which lies outside of the planning area. It is bounded on the south by an east-west trending basement ridge (Kotzebue Arch) that parallels the Seward Peninsula and may be an offshore extension of the Kobuk fault zone.

The basement throughout the area probably consists of Late Cretaceous or older rocks of the Brooks Range orogen. On the basis of seismic reflection character, refraction velocities, and relative stratigraphic position, the basin fill is probably Late Cretaceous to Paleogene nonmarine mudstones, siltstones, and sandstones, overlain by Neogene marine and nonmarine shales, and possibly sandstones with a combined total thickness in places exceeding 17,000 feet (5,180 m.). The early Tertiary sediment fill is draped over the crest of basement highs and chaotically fills the intervening troughs. The later Tertiary sediments have filled the basin in subhorizontal layers.

Northwest-southeast trending normal faults in the northern Hope Basin and east-west trending basement ridges in the southern Hope Basin are the dominant structural features. Generally, the basement is faulted into a ridge and trough configuration. The crests of some of these ridges are as close as 2,500 feet (760 m.) from the seafloor, and the basement in the troughs reaches depths as great as 17,000 feet (5,180 m.). In the northern part of the area, the ridges are essentially horst blocks or tilted normal fault blocks, and in the southern part, the linear ridges may be related to major strike-slip tectonics of the Kobuk fault zone. Basement faulting appears to have begun in the Late Cretaceous and continued into the late Tertiary. Tertiary normal faulting is of at least two generations: that directly related to active basement faulting and that created by compaction of the sedimentary section over basement highs.

Petroleum Potential

Two onshore stratigraphic test wells, the Nimiuk Point No. 1 and the Cape Espenberg No. 1 wells, were drilled by Standard Oil of California north and south of the entrance to Kotzebue Sound, just east of the planning area in 1974 and 1975.

The Kotzebue Sound wells penetrated from 3,500 to 4,000 feet (1,070 to 1,220 m.) of Quaternary sediments and from 2,500 to 4,000 feet (760 to 1,220 m.) of Tertiary rocks that lie on Devonian or older metasedimentary basement. The rocks in these wells show excellent reservoir properties with an average sand content for the total section of over 50 percent and average porosities over 25 percent. However, these rocks are part of the slightly younger Kotzebue Basin, which is separated from Hope Basin by the Kotzebue Arch, and may not be representative of the older, deeper offshore basin.

Many structural, stratigraphic, and fault traps may exist in the basin on the crest of, or adjacent to, the basement horst blocks. However, because of poor potential for source rocks in the pre-Tertiary basement and the generally thin, thermally immature Tertiary sedimentary section, the prospect for oil accumulation is low, with the possible exception of traps adjacent to locally thicker sections.

Chukchi Sea

Regional Geology

The Chukchi Sea Planning Area encompasses approximately 49,000 square miles (127,000 sq. km.) and is located on the northwestern-most extension of the Alaska OCS. The planning area contains three stratigraphic basins: the North Chukchi Basin (Tertiary), the Hanna Trough (Late Paleozoic to Late Mesozoic), and the Northern Hope Basin (Tertiary). Each exhibits a distinct stratigraphic sequence and has contrasting but tectonically-related structural elements. Hope Basin and the Hanna Trough are separated by a prominent structural feature, the Herald Arch and the associated Fold and Thrust Belt. The Hanna Trough extends north from the Herald Arch structural lineament which trends northwest from Cape Lisburne. This province comprises approximately 90 percent of the planning area. South of the Herald Arch lies the Northern Hope Basin, so named because it is an extension of the stratigraphy and structure of the Hope Basin located immediately south.

Three stratigraphic sequences are present in the Hanna Trough: Franklinian, Ellesmerian, and Brookian. They appear to be an offshore extension of regional western North Slope stratigraphy. The combined thickness of the Ellesmerian and Brookian sedimentary section in places exceeds 40,000 feet (12,200 m.). These three sequences represent stages in the tectonic development and depositional history of the basin. The Franklinian sequence encompasses Cambrian to Middle Devonian rocks which were metamorphosed during a Devonian orogeny and which constitute economic basement on the North Slope. The Ellesmerian sequence, Late Devonian to Early Cretaceous in age, is comprised of transgressive shallow shelf marine carbonates, marine and nonmarine sandstone, and shale derived from a northerly source terrane. The Brookian sequence, Early Cretaceous to present in age, is comprised of deep water to nonmarine northwardly prograding deltaic sediments.

In the Northern Hope Basin, block-faulted pre-Late Cretaceous basement rocks are believed to be overlain by nonmarine to marine Tertiary clastic rocks reaching a thickness, in places, of 15,000 feet (4,500 m.).

The significant structural elements can be divided into two groups based on time of formation: (1) the Paleozoic elements which include the Arctic Platform, Chukchi Platform, and the Hanna Trough; (2) the Mesozoic to

Cenozoic elements which include the North Chukchi Basin, the North Chukchi High, located east of this basin, the Northern Hope Basin, the Herald Arch and associated Fold and Thrust Belt, the Hanna Wrench Zone, which is a zone of strike-slip faulting extending from the Chukchi Platform, across the northern portion of the Hanna Trough, to the Chukchi High, and the Colville Trough which is the onshore extension of the Hanna Trough.

Petroleum Potential

Although considerable interest has been exhibited by industry in the past few years, no wells have been drilled in the Chukchi Sea. Therefore, it is necessary to extrapolate stratigraphic relationships into the planning area from existing geological and geophysical data that have been acquired in the adjacent National Petroleum Reserve in Alaska (NPRA). Exploration efforts in the NPRA began in 1904 with surface geologic exploration, and they continue at present. No commercial oil or gas fields have been discovered. Geologic data obtained from wells in the western NPRA were used to delineate potential source and reservoir rocks in the Chukchi Sea Planning Area.

Based on their high organic carbon content and high percentage of oil-prone kerogen, the best potential source rocks in the western NPRA and in the Hanna Trough appear to be the Shublik Formation and the Kingak Shale of the Ellesmerian sequence, and the Pebble Shale of the Brookian sequence. Vitrinite reflectance values indicate that these rocks increase in thermal maturity and lie below the oil window to the south towards the Colville (Hanna) Trough.

The most prospective reservoirs in the planning area would appear to be the Lisburne Group, the Sadlerochit Group, and the Endicott Group, all of which are oil productive or potentially productive in the Prudhoe Bay area. Sandstones which occur at the base of the Pebble Shale also form potential reservoirs in the northwestern NPRA and in the nearby Chukchi shelf area.

Both structural and stratigraphic traps are present in the planning area. Structural traps predominate in the Hanna Trough, the North Chukchi Basin, the Fold and Thrust Belt, the Hanna Wrench Zone, and the Northern Hope Basin. Stratigraphic traps may predominate on the flanks of the Arctic Platform and the Chukchi Platform areas, but they are difficult to identify on seismic data without well control.

The areas with the highest hydrocarbon potential appear to be the northeastern and western portions of the planning area: the North Chukchi Basin, the Hanna Trough, and the flanks of Arctic and Chukchi Platforms.

Beaufort Sea

Regional Geology

Major depocenters of the Beaufort Sea Planning Area extend some 500 miles (800 km.) along the northern continental margin of Alaska from the Canadian border to 162° west longitude where the planning area borders the Chukchi Sea Planning Area. The planning area encompasses approximately 79,000 square miles (205,000 sq. km.). The Beaufort shelf is divisible into two major provinces including: (1) a landward area underlain by continental crust termed the Arctic Platform; (2) an area near the shelf-edge where thick clastic wedges of Cretaceous and Tertiary sediments were deposited upon transitional crust and Mesozoic oceanic crust. The highly faulted boundary between these provinces is termed the Hinge Line. Primary depocenters within these provinces include the Arctic Platform, the Northeast Chukchi Basin, the Dinkum Graben, the Nuwuk Basin, the Kaktovik Basin, and the Arctic Basin.

Acoustic and economic basement on the Arctic Platform consists of a metamorphic complex (Franklinian sequence) which represents the roots of an Early Paleozoic orogen. Basement is overlain by Devonian through Early Cretaceous strata (Ellesmerian sequence) deposited in a stable shelf setting. The Ellesmerian sequence thins and onlaps northward toward the ancient landmass which once existed north of the modern Beaufort continental margin. Ellesmerian sedimentation terminated in Early Cretaceous time with the thermal uplift of the Arctic Platform prior to rifting in the vicinity of the present shelf edge. This uplift produced a regionally extensive Lower Cretaceous unconformity and erosional truncation of Ellesmerian strata across the northern part of the Arctic Platform. The subsequent onset of actual rift displacement produced rift zone grabens which were filled with Lower Cretaceous sediments (termed the Rift sequence) derived from adjacent highlands. Cooling and subsidence of the near-rift crust following breakup created the modern Barrow Arch. By Late Cretaceous time, an immense clastic wedge (termed the Brookian sequence) prograding northward from the Brooks Range orogen inundated and spilled over the Barrow Arch into shelf-edge depocenters, such as the Nuwuk and Kaktovik Basins, along the newly formed, fault-bounded, Beaufort continental margin.

Sediment thickness for the Arctic Platform range from less than 3,000 feet (900 m.) at Point Barrow to at least 30,000 feet (9,000 m.) in the Northeast Chukchi Basin west of Barrow. Sediment thickness in the east-southeast trending Dinkum Graben, which occurs within the eastern portion of the Arctic Platform, may exceed 35,000 feet (10,500 m.).

Seaward of the Hinge Line, in the Nuwuk Basin, up to 40,000 feet (12,200 m.) of Brookian clastic sedimentary fill spans the continental basement of the Arctic Platform northward to transitional or oceanic crust of the Arctic Basin. Most of the eastern Beaufort Shelf is underlain by the Kaktovik Basin which is filled with Brookian sediments which were deposited in a shelf-edge or slope setting. The total thickness of sedimentary rocks within the Kaktovik Basin exceeds 40,000 feet (12,200 m.). The principal structural features are large, detached and compressional folds, and zones of en echelon folds which intervene between fault-bounded basins.

Sediment thickness in the southern parts of the deep-water Arctic Basin range between 20,000 to 33,000 feet (6,100 to 10,060 m.). These sediments rest directly upon oceanic crust. Diapiric folds and ridges are common in the deep Arctic Basin east of 145° west longitude.

Petroleum Potential

Exploration for hydrocarbons in the area has been conducted since 1944, when the Department of the Navy began drilling exploratory tests at several localities in the central and northernmost parts of the Arctic coastal plain. This work led to the discovery of several subcommercial oil and gas fields. Privately funded exploration elsewhere on the coastal plain led to the discovery of the supergiant Prudhoe Bay field in 1968. This field contains remaining recoverable reserves in excess of 5 billion barrels of oil (original reserves, 10 billion barrels) and 26 trillion cubic feet of gas. It sparked oil development in northern Alaska and afforded construction of an essential pipeline transportation system from the field to an ice-free port in southern Alaska. Because of the existence of this infrastructure, satellite accumulations in the vicinity of Prudhoe Bay, which would otherwise be considered subcommercial (ranging from 0.3 to 1.0 billion barrels), are now being brought into production. Drilling offshore in Federal waters commenced in 1981. The Seal Island discovery, 12 miles (20 km.) northwest of Prudhoe Bay, was announced by Shell in early 1984, and it appears to extend from State to Federal waters. Total recoverable reserves in the Seal Island structure are presently estimated at 300 million barrels.

All major North Slope oil accumulations are lodged in Ellesmerian sequence reservoir formations, and any part of the Arctic Platform where these rocks are preserved is considered highly prospective. Known accumulations are trapped by a complex composite of sealing surfaces, including faults, structural dip, and truncation at regional unconformities such as that associated with the major Lower Cretaceous erosional event. The northernmost parts of the Arctic Platform are less prospective because of the absence of Ellesmerian formations, but they contain rift zone grabens within which reservoir rocks deposited as part of the Rift sequence may be present. Excellent oil source beds are thought to be present at levels of thermal maturity adequate for oil generation and expulsion in all parts of the Beaufort continental shelf within the planning area.

Numerous structural and stratigraphic traps exist within the thick Brookian clastic wedge seaward of the Hinge Line. Any potential reservoir formations in this area were most likely deposited in a deltaic or prodeltaic setting, suggesting that individual accumulations may be small due to reservoir lenticularity. This has been commonly, but not universally, found to be the case in analogous geological provinces, such as the Mackenzie Delta area of the Canadian Beaufort shelf. Rotational folds associated with listric faulting are the most attractive targets in the Nuwuk Basin, while compressional folds and fault traps form the most prevalant trap types in the Kaktovik Basin.

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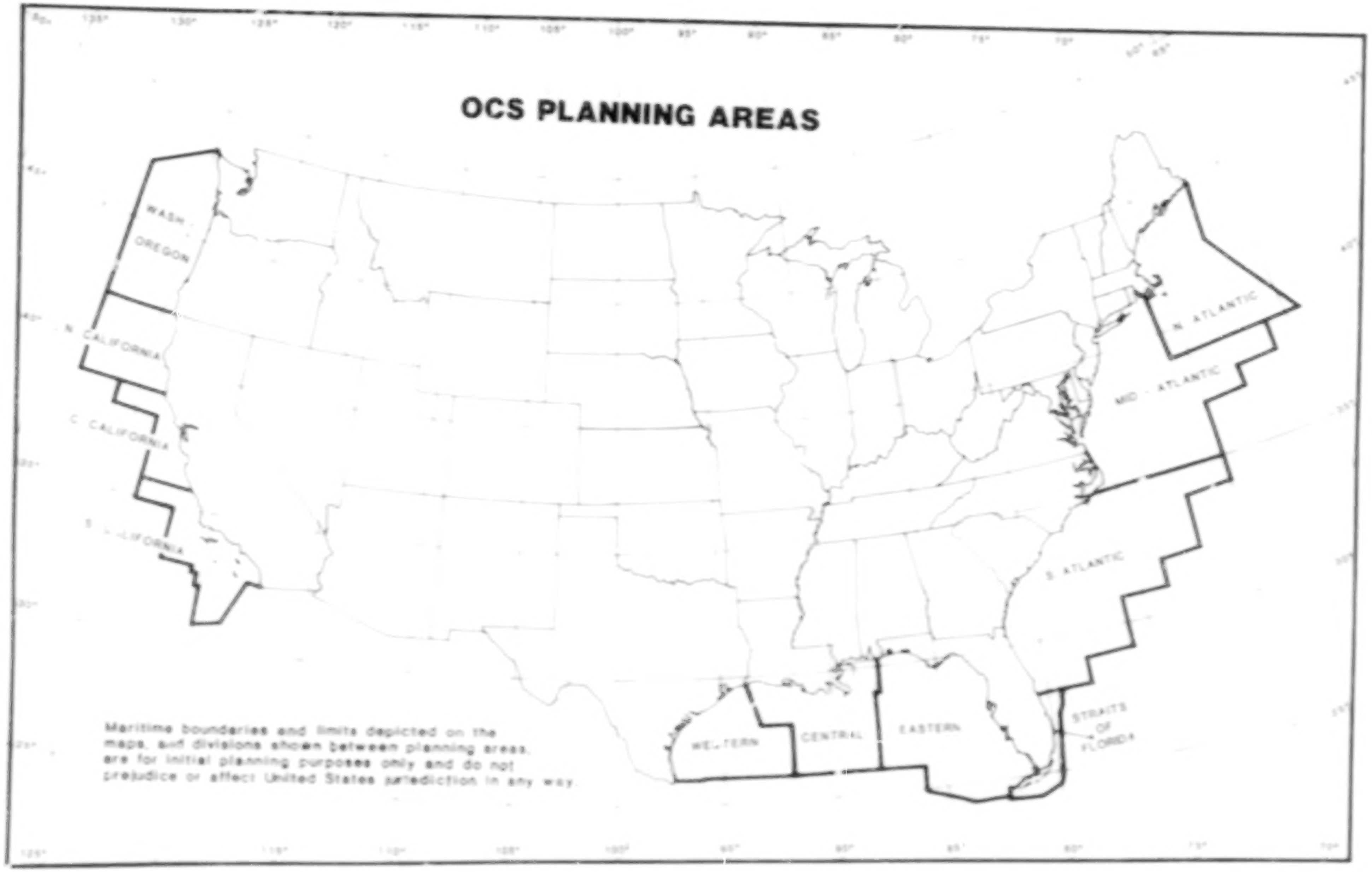

Maritime boundaries and limits depicted on the maps, and divisions shown between planning areas, are for initial planning purposes only and do not prejudice or affect United States jurisdiction in any way.

FIGURE 1. Outer Continental Shelf planning areas—lower 48 states

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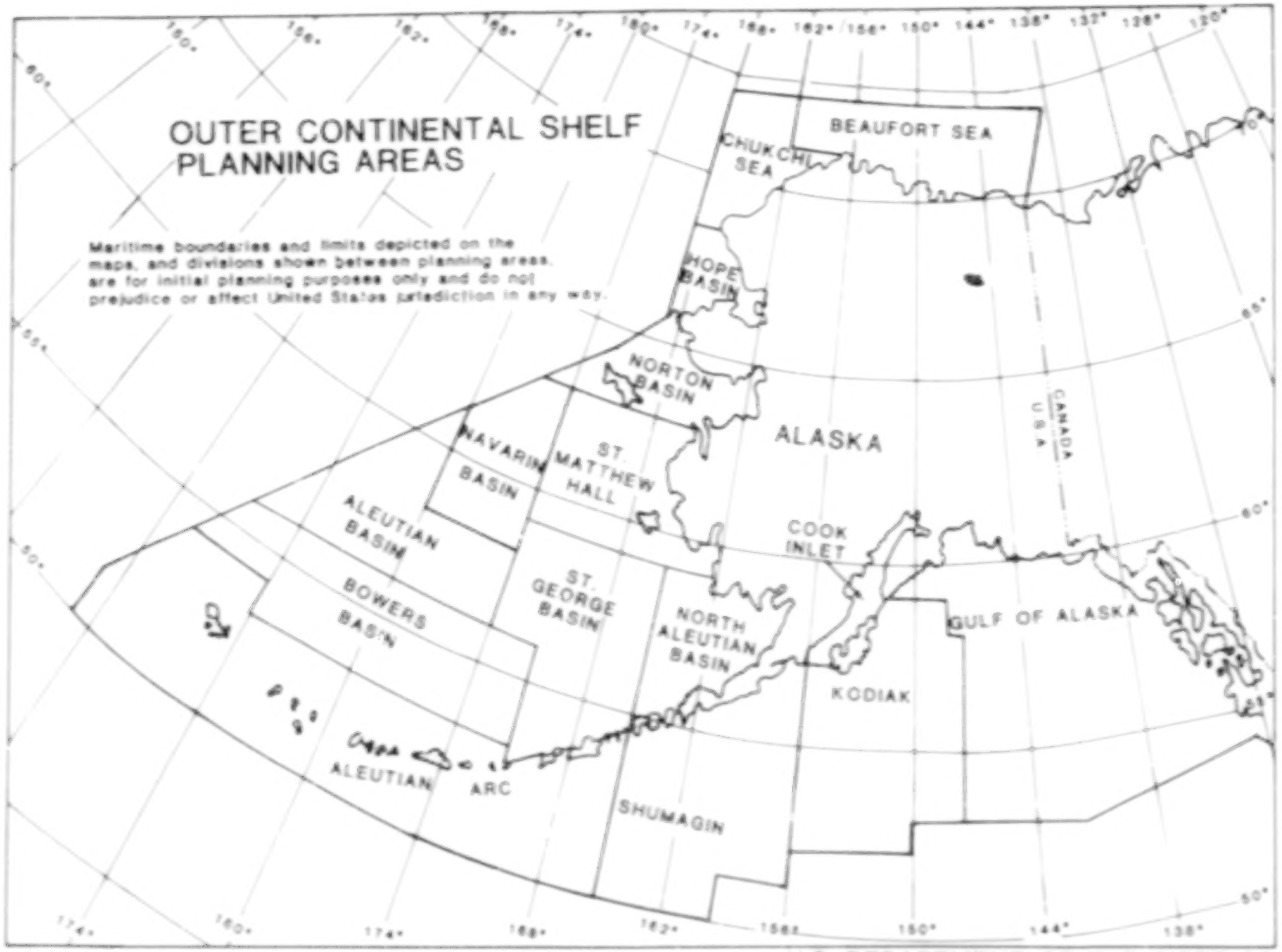

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FIGURE 2. Outer Continental Shelf planning areas—Alaska

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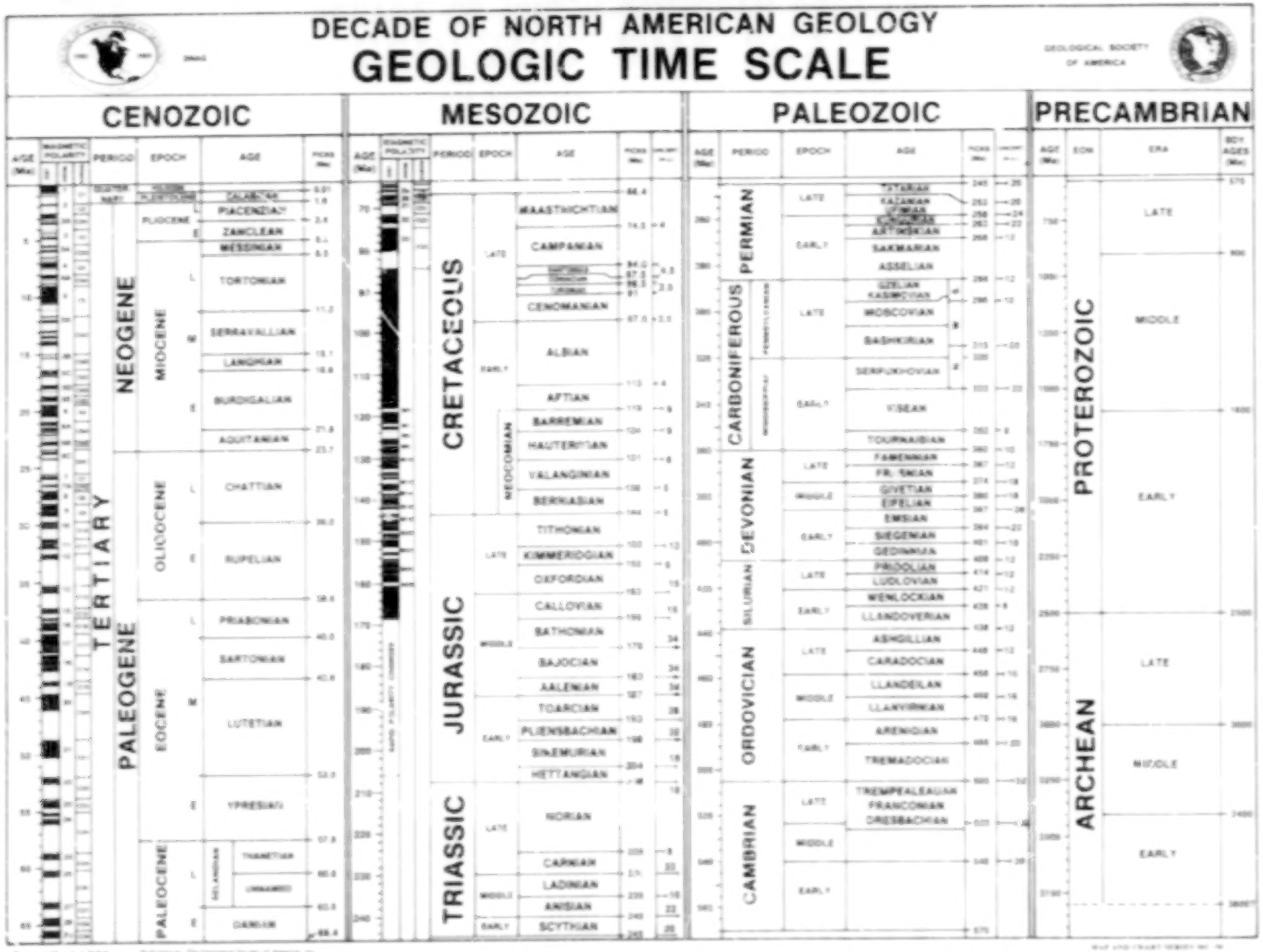

FIGURE 3. Geologic time scale

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